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Invention: EXHAUST GAS PURIFICATION SYSTEM OF INTERNAL COMBUSTION ENGINE

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SPECIFICATION

EXHAUST GAS PURIFICATION SYSTEM OF INTERNAL COMBUSTION ENGINE

CROSS REFERENCE TO RELATED APPLICATION

This application is based on and incorporates herein by reference Japanese Patent Application No. 2003-5595 filed on January 14, 2003.

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

The present invention relates to an exhaust gas purification system of an internal combustion engine having an exhaust gas after-treatment device such as a particulate filter, which has a catalyst, in an exhaust passage. Specifically, the present invention relates to an exhaust gas purification system having means for avoiding catalyst poisoning due to hydrocarbon supplied to an exhaust gas after-treatment device.

2. DESCRIPTION OF RELATED ART:

Recently, an exhaust gas purification system for treating gas discharged from an internal combustion engine with a catalyst or a filter in order to inhibit discharge of harmful components has been emphasized as environment-protecting measures. As an example of such an exhaust gas purification system, there is an exhaust gas purification system for collecting particulate matters discharged from a diesel engine with a diesel particulate filter (a DPF) disposed in an exhaust pipe. The exhaust gas purification

system combusts and eliminates the collected particulate matters regularly. Thus, the DPF is regenerated and can be used continuously.

The regeneration of the DPF is performed when a quantity of the particulate matter accumulated on the surface of the DPF (a PM accumulation quantity) becomes higher than a predetermined quantity. The PM accumulation quantity is calculated based on a pressure difference across the DPF. In order to regenerate the DPF, unburned hydrocarbon (HC) is supplied to the DPF by performing a post injection and the like. The supplied hydrocarbon is combusted with an oxidization catalyst, which is supported on the surface of the DPF in advance. Heat generated through the combustion of the unburned hydrocarbon can increase the temperature of the DPF above a certain temperature (for instance, 600°C), above which the particulate matters can be combusted.

However, if the temperature of the DPF is low at that time, velocity of the catalytic reaction is reduced. If a large amount of the hydrocarbon is supplied in that state, the supplied hydrocarbon will adhere to a surface of the catalyst. As a result, diffusion of the exhaust gas including the harmful components to the neighborhood of the catalyst is inhibited, so the catalytic reaction is hindered. Thus, a problem of catalyst poisoning due to the hydrocarbon (hydrocarbon poisoning) is caused. The hydrocarbon poisoning is caused by physical adhesion of the hydrocarbon to the catalyst. Therefore, catalytic activity can be restored by

holding the DPF at high temperature and by promoting detachment of the hydrocarbon adhering to the catalyst. A technology employing the above principle and relating to a regenerating operation of the catalyst poisoned with the hydrocarbon is disclosed in Japanese Patent Unexamined Publication No. H11-257125 (a patent document 1), for instance.

A system for purifying nitrogen oxides (NOx) with the catalyst is disclosed in the patent document 1. This system includes determining means for calculating a quantity of the hydrocarbon adhering to the catalyst and for determining the catalyst poisoning based on whether the adhering quantity of the hydrocarbon is greater than a predetermined quantity or not. Thus, the system performs an operation for eliminating the catalyst poisoning when it is determined that the catalyst is poisoned. The operation for eliminating the catalyst poisoning is performed by closing an intake throttle valve and by opening an exhaust gas recirculation valve (an EGR valve) of the exhaust gas. Thus, the temperature decrease of the catalyst is prevented. Moreover, the detachment and the oxidation of the hydrocarbon are promoted and the temperature of the catalyst is increased with the oxidative reaction heat. In the system, the hydrocarbon is added upstream of the catalyst in order to reduce and purify the nitrogen oxides.

More specifically, the method disclosed in the patent document 1 permits the generation of the catalyst poisoning due to the hydrocarbon and takes measures only after the hydrocarbon poisoning is generated. However, if the catalyst

is once poisoned with the hydrocarbon, it takes long time to eliminate the poisoning. Moreover, the purification of the harmful components cannot be performed until the hydrocarbon poisoning is eliminated. Specifically, if an inlet end surface of the DPF is exposed to the high-temperature exhaust gas after the inlet end surface is poisoned with the hydrocarbon, the adhering hydrocarbon will be carbonized. There is a possibility that the carbonized hydrocarbon may block the inlet end surface of the DPF in the worst case. In order to eliminate the carbonized hydrocarbon, the carbonized hydrocarbon must be burned by holding the blocked portion at very high temperature (600°C or higher, for instance) for a long time. However, it is difficult to maintain the high temperature for a long time in a normal operating state occupying a major part of actual travel, where the temperature of the exhaust gas is low (300°C or lower, for instance). As a result, fuel consumption will be increased largely.

Therefore, the hydrocarbon poisoning itself should be avoided instead of taking the measures after the hydrocarbon poisoning is caused. Specifically, the DPF requires the supply of the large amount of the hydrocarbon through the post injection and the like in order to combust the accumulated particulate matters. Therefore, the DPF is prone to be poisoned with the hydrocarbon. If the hydrocarbon poisoning is caused, the temperature of the DPF cannot be increased quickly, so the particulate matters cannot be combusted suitably. Therefore, avoidance of the hydrocarbon poisoning

is important.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an exhaust gas purification system of an internal combustion engine capable of avoiding poisoning of a catalyst, which is disposed in an exhaust gas after-treatment device, due to hydrocarbon. Thus, an operation for recovering catalytic activity can be omitted, so deterioration of capability of combusting particulate matters or capability of purifying harmful components due to the catalytic activity recovering operation can be prevented. Meanwhile, carbonization of the adhering hydrocarbon can be prevented. Thus, performance of the catalyst can be maintained for a long time and a highly reliable device can be provided.

According to an aspect of the present invention, an exhaust gas purification system of an internal combustion engine includes an exhaust gas after-treatment device, temperature sensing means, hydrocarbon supplying means, and hydrocarbon supply quantity controlling means. The exhaust gas after-treatment device is disposed in an exhaust passage of the internal combustion engine and supports a catalyst on its surface. The temperature sensing means estimates the temperature of the exhaust gas after-treatment device. The hydrocarbon supplying means supplies hydrocarbon to the exhaust gas after-treatment device. The hydrocarbon supply quantity controlling means determines an upper limit value of

a permissible quantity of the hydrocarbon supplied to the exhaust gas after-treatment device in accordance with the temperature of the exhaust gas after-treatment device, which is estimated by the temperature sensing means. The hydrocarbon supply quantity controlling means controls the hydrocarbon supplying means so that the quantity of the hydrocarbon supplied to the exhaust gas after-treatment device does not exceed the upper limit value.

The temperature of the exhaust gas after-treatment device greatly affects the poisoning due to the hydrocarbon (the hydrocarbon poisoning). Therefore, the upper limit value of the permissible quantity of the supplied hydrocarbon is determined in accordance with the temperature of the exhaust gas after-treatment device. Meanwhile, the hydrocarbon supplying means is controlled so that the quantity of the supplied hydrocarbon does not exceed the upper limit value. Thus, the hydrocarbon poisoning itself can be prevented, and an operation for recovering catalytic activity is unnecessary. Therefore, problems of decrease in purifying performance during the catalytic ability recovering operation or carbonization of adhering hydrocarbon can be prevented. Thus, a highly reliable device with high catalytic performance can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of an embodiment will be appreciated, as well as methods of operation and the function

of the related parts, from a study of the following detailed description, the appended claims, and the drawings, all of which form a part of this application. In the drawings:

Fig. 1 is a schematic diagram showing an exhaust gas purification system of an internal combustion engine according to an embodiment of the present invention;

Fig. 2 is a graph showing an area where hydrocarbon poisoning is caused, based on coordinate axes of DPF inlet gas temperature and DPF inlet gas hydrocarbon quantity;

Fig. 3 is a graph showing a quantity of hydrocarbon generated through combustion in the engine, based on coordinate axes of engine rotation speed and output torque;

Fig. 4 is a graph showing post injection quantity based on coordinate axes of the engine rotation speed and the output torque;

Fig. 5 is a graph showing a relationship between the post injection quantity and combusted part of the post injection quantity based on the output torque;

Fig. 6 is a flowchart showing control performed by an electronic control unit of the exhaust gas purification system according to the present embodiment; and

Fig. 7 is a time chart showing an effect of the exhaust gas purification system according to the present embodiment.

DETAILED DESCRIPTION OF THE REFERRED EMBODIMENT

Referring to Fig. 1, an exhaust gas purification system of a diesel engine 1 according to the present embodiment is

illustrated. A diesel particulate filter (a DPF) 3 as an exhaust gas after-treatment device is disposed between an upstream exhaust pipe 2a and a downstream exhaust pipe 2b as exhaust passages of the engine 1. The DPF 3 supports an oxidization catalyst on its surface. For instance, the DPF 3 is formed of heat-resistant ceramics such as cordierite in the shape of a honeycomb having a multiplicity of cells as gas passages. An inlet or an outlet of each cell of the DPF 3 is blocked alternately. The oxidation catalyst such as platinum is applied on the surfaces of cell walls of the DPF 3. Exhaust gas discharged from the engine 1 flows downstream while passing through the porous partition walls of the DPF 3. Meanwhile, particulate matters included in the exhaust gas are collected by the partition walls and are gradually accumulated in the DPF 3.

An exhaust gas temperature sensor 41 is disposed in the upstream exhaust pipe 2a upstream of the DPF 3. Another exhaust gas temperature sensor 42 is disposed in the downstream exhaust pipe 2b downstream of the DPF 3. The exhaust gas temperature sensors 41, 42 are connected to an electronic control unit (an ECU) 6. The exhaust gas temperature sensor 41 senses temperature of the exhaust gas at an inlet of the DPF 3 and outputs the temperature to the ECU 6. The exhaust gas temperature sensor 42 senses the temperature of the exhaust gas at an outlet of the DPF 3 and outputs the temperature to the ECU 6. The upstream exhaust gas temperature sensor 41 is used as temperature sensing means for

estimating the temperature of the DPF 3 in hydrocarbon supply quantity control (explained after). An airflow meter (an intake quantity sensor) 43 is disposed in an intake pipe 11 of the engine 1. The airflow meter 43 senses air intake quantity and outputs the intake quantity to the ECU 6. The intake pipe 11 is connected with the upstream exhaust pipe 2a upstream of the DPF 3 through an exhaust gas recirculation passage (an EGR passage) 71 having an exhaust gas recirculation valve (an EGR valve) 7. The ECU 6 controls the drive of the EGR valve 7.

A pressure difference sensor 5 is connected to the upstream exhaust pipe 2a and the downstream exhaust pipe 2b for measuring a quantity of the particulate matters collected and accumulated in the DPF 3 (a particulate matter accumulation quantity, hereafter) by sensing a pressure difference across the DPF 3. An end of the pressure difference sensor 5 is connected with the upstream exhaust pipe 2a through a pressure introduction pipe 51. The other end of the pressure difference sensor 5 is connected with the downstream exhaust pipe 2b through another pressure introduction pipe 52. The pressure difference sensor 5 outputs a signal corresponding to the pressure difference across the DPF 3 to the ECU 6. The ECU 6 calculates the particulate matter accumulation quantity based on the pressure difference across the DPF 3. The ECU 6 performs regeneration control of the DPF 3 when the particulate matter accumulation quantity exceeds a predetermined quantity.

Moreover, the ECU 6 is connected with various sensors

such as an accelerator position sensor 61 or a rotation speed sensor 62. The ECU 6 detects an operating condition based on detection signals outputted from the various sensors and calculates optimum fuel injection quantity, injection timing, injection pressure and the like in accordance with the operating condition. Thus, the ECU 6 controls fuel injection into the engine 1. The ECU 6 controls a quantity of the exhaust gas recirculated to the intake air (an EGR quantity) by regulating an opening degree of the EGR valve 7.

The ECU 6 includes hydrocarbon supplying means for supplying the hydrocarbon to the DPF 3 in order to combust the accumulated particulate matters in the regeneration of the DPF 3. The supplied hydrocarbon is combusted by the oxidation catalyst supported on the surface of the sell walls of the DPF 3. The heat generated through the combustion of the hydrocarbon increases the temperature of the DPF 3 above a certain temperature, at which the particulate matters can be combusted. In order to supply the hydrocarbon, the hydrocarbon supplying means performs an operation such as a post injection, retardation of fuel injection timing and restriction of the intake air, or a combination of them.

However, if the temperature of the DPF 3 is low at that time, there is a possibility that the hydrocarbon poisoning may be caused. If a large amount of the hydrocarbon is supplied to the catalyst when the velocity of the oxidation reaction by the oxidation catalyst is low because of the low temperature of the catalyst, the supplied hydrocarbon will

adhere to the surface of the catalyst. As a result, the catalytic reaction is hindered because diffusion of the gas including the harmful components to the neighborhood of the catalyst (the platinum and the like) is inhibited. This phenomenon is the hydrocarbon poisoning. The hydrocarbon poisoning is caused by physical adhesion of the hydrocarbon to the catalyst. Therefore, the hydrocarbon poisoning can be eliminated reversibly by decreasing the hydrocarbon supply quantity and by holding the catalyst at high temperature.

Therefore, in the present embodiment, the ECU 6 includes hydrocarbon supply quantity controlling means for determining an upper limit value of the permissible quantity of the hydrocarbon supplied to the DPF 3 in accordance with the temperature of the DPF 3 and for controlling the hydrocarbon supplying means so that the quantity of the actually-supplied hydrocarbon does not exceed the upper limit value. A graph shown in Fig. 2 is based on experimentation performed by the inventors. The graph in Fig. 2 shows an area "A" where the hydrocarbon poisoning is not caused and another area "B" where the hydrocarbon poisoning is caused, based on axes of the exhaust gas temperature upstream of the DPF 3, or DPF inlet gas temperature Tin (°C), and the quantity of the hydrocarbon supplied to the DPF 3, or an inlet gas hydrocarbon quantity HCin (g/min). In Fig. 2, cross marks represent experimental results, in which the hydrocarbon poisoning is caused. Round marks represent the experimental results, in which the hydrocarbon poisoning is not caused. In Fig. 2, it is

determined that the hydrocarbon poisoning is caused if the change in the DPF temperature TDPF (or an increase in the DPF temperature TDPF per unit time) after the hydrocarbon is supplied is less than a predetermined value. Otherwise, it is determined that the hydrocarbon poisoning is not caused. It is because the catalyst temperature will increase quickly if the hydrocarbon poisoning is not caused, and the increase in the catalyst temperature will be reduced if the hydrocarbon poisoning is caused.

As shown in Fig. 2, whether the hydrocarbon poisoning is caused or not greatly depends on the temperature Tin of the exhaust gas, which includes the hydrocarbon supplied to the DPF 3. If the temperature Tin of the exhaust gas upstream of the DPF 3 is equal to or lower than 250°C, the possibility of the hydrocarbon poisoning is very high. If the temperature of the exhaust gas upstream of the DPF 3 is higher than 250°C, the possibility of the hydrocarbon poisoning is reduced as the temperature Tin of the exhaust gas upstream of the DPF 3 increases. In this case, the upper limit value HCup of the permissible quantity of the hydrocarbon supplied to the DPF 3 is increased as the temperature Tin of the exhaust gas upstream of the DPF 3 increases. The upper limit value HCup of the hydrocarbon for preventing the hydrocarbon poisoning is determined based on the graph in Fig. 2, assuming that the DPF temperature TDPF coincides with the DPF inlet gas temperature Tin sensed by the exhaust gas temperature sensor 41. The ECU 6 includes hydrocarbon quantity sensing means for sensing the

quantity of the hydrocarbon, which is included in the exhaust gas and is supplied to the DPF 3. Then, the ECU 6 determines whether the hydrocarbon poisoning will be caused or not by comparing the sensed hydrocarbon quantity with the upper limit value. The hydrocarbon quantity sensing means calculates the quantity HCact of the hydrocarbon actually supplied to the DPF 3 from a combustion-originated quantity HCcom of the hydrocarbon generated through the combustion in the engine 1 and a supply-originated quantity HCsup of the hydrocarbon supplied by the hydrocarbon supplying means, based on a following formula (1).

$$HCact = HCcom + HCsup, \quad (1)$$

More specifically, the quantity HCact of the hydrocarbon actually supplied to the DPF 3, which causes the hydrocarbon poisoning, is the summation of the combustion-originated quantity HCcom of the hydrocarbon generated through the combustion in the engine 1 and the supply-originated quantity HCsup of the hydrocarbon supplied by the hydrocarbon supplying means through the post injection and the like.

More specifically, the combustion-originated quantity HCcom of the hydrocarbon is calculated based on the operating condition of the engine such as engine rotation speed NE and the output torque.

For instance, a graph in Fig. 3 shows the combustion-originated quantity HCcom of the hydrocarbon generated through

the combustion in the engine 1, based on axes of the engine rotation speed NE and the output torque. The combustion-originated quantity HCcom increases along an arrow mark in Fig. 3. A solid line "MAX" in Fig. 3 represents the maximum value of the output torque. The relationship between the operating condition and the combustion-originated quantity HCcom is stored in advance, so the combustion-originated quantity HCcom of the hydrocarbon can be calculated easily from the engine rotation speed NE and the output torque.

The supply-originated quantity HCsup of the hydrocarbon supplied by the hydrocarbon supplying means can be calculated based on an operation degree of the hydrocarbon supplying means (for instance, the post injection quantity) and the engine condition (for instance, the output torque).

A graph in Fig. 4 shows the post injection quantity Qpost under various engine operating conditions based on axes of the engine rotation speed NE and the output torque. The post injection quantity Qpost increases along an arrow mark in Fig. 4. The post injection quantity Qpost is basic post injection quantity adjusted for each engine operating condition in advance. Part of the fuel injected in the post injection is combusted in the cylinder. Therefore, the post injection quantity Qpost does not necessarily coincide with the actual quantity of the hydrocarbon supplied through the post injection. Therefore, in the present embodiment, the supply-originated quantity HCsup of the hydrocarbon supplied by the hydrocarbon supplying means is calculated, while

considering the quantity Qcom of the hydrocarbon combusted in the cylinder.

The quantity HCsup of the hydrocarbon actually supplied to the DPF 3 through the post injection varies in accordance with the engine output torque and the like. It is because the quantity Qcom of the fuel combusted in the cylinder, which is part of the post injection quantity Qpost, changes in accordance with the temperature in the cylinder and the post injection timing. Therefore, the quantity Qcom of the fuel combusted in the cylinder in the post injection quantity Qpost is calculated based on a graph in Fig. 5 showing the relationship between the post injection quantity Qpost and the quantity Qcom of the fuel combusted in the cylinder in the post injection quantity Qpost. In Fig. 5, a solid line "TL" represents the combusted quantity Qcom at the time when the output torque is large. A solid line "TM" represents the combusted quantity Qcom at the time when the output torque is medium. A solid line "TS" represents the combusted quantity Qcom at the time when the output torque is small. The supply-originated quantity HCsup of the hydrocarbon supplied by the hydrocarbon supplying means can be calculated from the basic post injection quantity Qpost and the quantity Qcom of the fuel combusted in the cylinder in the post injection quantity Qpost, based on a following formula (2). In the formula (2), C1 represents a constant value for converting the quantity of the injected fuel into the quantity of the hydrocarbon.

$$HCsup = (Qpost - Qcom) \times C1, \quad (2)$$

The ECU 6 compares the quantity of the supplied hydrocarbon, which is calculated by the hydrocarbon quantity sensing means, with the upper limit value HCup of the hydrocarbon quantity for preventing the hydrocarbon poisoning. If the quantity of the supplied hydrocarbon exceeds the upper limit value HCup, the ECU 6 determines that the hydrocarbon poisoning can be caused and the quantity of the hydrocarbon supplied by the hydrocarbon supplying means through the post injection and the like is decreased. Thus, the generation of the hydrocarbon poisoning can be prevented by controlling the quantity of the supplied hydrocarbon below the upper limit value HCup.

The basic post injection quantity Qpost shown in Fig. 4 is calculated through bench testing of the engine 1 in a state where the temperature of the DPF 3 is stabilized sufficiently. Generally, in order to increase the temperature of the DPF 3 quickly, the basic post injection quantity Qpost is determined so that the actual post injection quantity becomes as great as possible. Therefore, there is a possibility that the temperature of the DPF 3 at the time when the system is actually mounted on a vehicle and is operated does not coincide with the temperature of the DPF 3 at the time when the basic post injection quantity Qpost is calculated in the bench testing of the engine 1 even if the operating conditions of the engine 1 are the same. In particular, such a situation

will occur in a period immediately after the engine start or in the early stage of the acceleration, for instance. In order to avoid such a situation, the system of the present embodiment corrects the supplying quantity of the hydrocarbon and supplies the appropriate quantity of the hydrocarbon. Thus, the hydrocarbon poisoning can be prevented.

Next, hydrocarbon supply quantity control performed by the ECU 6 will be explained based on a flowchart shown in Fig. 6.

First, in Step S101, it is determined whether the hydrocarbon supplying means is supplying the hydrocarbon to the DPF 3 or not. In the present embodiment, it is determined whether the condition for performing the post injection is established or not in Step S101. If the result of the determination in Step S101 is "YES", the processing proceeds to Step S102. In Step S102, the engine rotation speed NE and the accelerator position ACCP are inputted from the rotation speed sensor 62 and the accelerator position sensor 61. Meanwhile, the temperature Tin of the exhaust gas upstream of the DPF 3 is inputted from the exhaust gas temperature sensor 41. If the result of the determination in Step S101 is "NO", the processing is ended without performing the post injection.

The post injection is performed to regenerate the DPF 3 by combusting the particulate matters when the particulate matter accumulation quantity exceeds the predetermined quantity. More specifically, a small amount of the fuel is additionally injected after the main fuel injection performed

for operating the engine, or during an expansion stroke after the top dead center. Thus, the unburned hydrocarbon is generated and the hydrocarbon is supplied to the DPF 3. The hydrocarbon supplied to the DPF 3 is combusted by the catalyst supported on the surface of the DPF 3. The DPF 3 is heated to high temperature (above 500°C, for instance) by the combustion heat, so the particulate matters on the surface of the DPF 3 are combusted. The similar effect can be exerted by retarding the fuel injection timing or by increasing the EGR quantity, in addition to the post injection.

Whether the particulate matter accumulation quantity has reached the predetermined quantity or not is determined by comparing the particulate matter accumulation quantity with the predetermined quantity. The particulate matter accumulation quantity is calculated based on the pressure difference across the DPF 3 sensed by the pressure difference sensor 5. The particulate matter accumulation quantity can be calculated based on the pressure difference across the DPF 3 because the pressure difference, which is generated when a predetermined quantity of the exhaust gas passes through the DPF 3, is correlated with the particulate matter accumulation quantity. The correlation is obtained in advance through experimentation and the like. The quantity of the exhaust gas is calculated from the air intake quantity sensed by the airflow meter 43, the temperature of the upstream side and the downstream side of the DPF 3 sensed by the exhaust gas temperature sensors 41, 42, the pressure difference sensed by

the pressure difference sensor 5 and the like.

Then, in Step S103, the combustion-originated quantity HCcom of the hydrocarbon discharged from the engine 1 is calculated from the engine rotation speed NE and the engine output torque calculated from the accelerator position ACCP, based on the relationship shown in Fig. 3. Then, in Step S104, the basic post injection quantity Qpost is calculated from the engine rotation speed NE and the engine output torque, based on Fig. 4.

Then, in Step S105, the quantity Qcom of the fuel combusted in the cylinder in the post injection quantity Qpost is calculated form the basic post injection quantity Qpost calculated in Step S104 and the engine output torque, based on Fig. 5. As shown in Fig. 5, as the output torque increases, the quantity Qcom of the fuel combusted in the cylinder increases and the temperature in the cylinder increases. Therefore, even if the post injection quantity Qpost is constant, the quantity Qcom of the fuel combusted in the cylinder increases as the output torque increases.

Then, in Step S106, the quantity HCact of the hydrocarbon actually supplied to the DFP 3 is calculated. First, supply-originated quantity HCsup of the hydrocarbon originating from the post injection is calculated from the basic post injection quantity Qpost and the quantity Qcom of the fuel combusted in the cylinder in the post injection quantity Qpost based on the formula (2).

Then, the quantity HCact of the hydrocarbon actually

supplied to the DPF 3 is calculated from the combustion-originated quantity HCcom of the hydrocarbon generated through the combustion in the engine 1 and the supply-originated quantity HCsup originating from the post injection, based on the formula (1).

Then, in Step S107, based on the relationship shown in Fig. 2, the upper limit value HCup of the actually supplied quantity HCact for preventing the hydrocarbon poisoning is calculated in accordance with the present temperature Tin of the exhaust gas upstream of the DPF 3, which is sensed in Step S102. Then, in Step S108, the quantity HCact of the hydrocarbon actually supplied to the DPF 3 calculated in Step S106 is compared with the upper limit value HCup calculated in Step S107. Thus, it is determined whether the quantity HCact of the hydrocarbon actually supplied to the DPF 3 is equal to or less than the upper limit value HCup. If the quantity HCact of the hydrocarbon actually supplied to the DPF 3 is greater than the upper limit value HCup, the processing proceeds to Step S109 and the post injection quantity Qpost is decreased to corrected post injection quantity Qpost' so that the quantity HCact of the hydrocarbon actually supplied to the DPF 3 coincides with the upper limit value HCup. Thus, the post injection quantity Qpost is restricted so that the actually supplied quantity HCact does not exceed the upper limit value HCup.

Then, the processing proceeds to Step S110 and the post injection is performed based on the corrected post injection

quantity Qpost'. In the case where the quantity HCact of the hydrocarbon actually supplied to the DPF 3 is equal to or less than the upper limit value HCup in Step S108, the processing proceeds to Step S110 and the post injection is performed.

Fig. 7 is a time chart showing an effect of the present embodiment. Conventionally, the supply of the large amount of the hydrocarbon is started at timing t1 as shown by a broken line "a" in Fig. 7 in order to combust the particulate matters even if the temperature Tin of the exhaust gas upstream of the DPF 3 is relatively low. Therefore, the hydrocarbon poisoning can be caused easily and the temperature TDPF of the DPF 3 does not increase quickly as shown by a broken line "c" in Fig. 7 because the catalytic reaction is hindered. To the contrary, in the present embodiment, the quantity HCact of the hydrocarbon supplied to the DPF 3 (the summation of the combustion-originated quantity HCcom and the supply-originated quantity HCsup) is regulated as shown by a solid line "b" in Fig. 7 in order to prevent the hydrocarbon poisoning. Therefore, the temperature TDPF of the DPF 3 can be increased quickly as shown by a solid line "d". As a result, the particulate matters accumulated on the surface of the DPF 3 can be combusted effectively, and the harmful components included in the exhaust gas can be purified effectively.

As explained above, in the present embodiment, the hydrocarbon poisoning can be precluded and the deterioration of the performance of the catalyst due to the adhesion of the hydrocarbon can be avoided. Moreover, the deterioration of

the fuel consumption due to the operation for eliminating the hydrocarbon poisoning can be avoided.

The present invention exerts a great effect when the present invention is applied to the DPF having the oxidation catalyst, to which a large amount of the hydrocarbon is supplied in order to combust the particulate matters. The present invention can be applied to the exhaust gas after-treatment device supporting other catalysts. More specifically, the present invention can be applied to a catalyst system employing a DPF with an oxidation catalyst, a nitrogen oxide removal catalyst, an oxidation catalyst or a three-way catalyst, or a combination of them such as a nitrogen oxide removal catalyst that reduces and purifies the nitrogen oxides by supplying the hydrocarbon, or a catalyst system for purifying the hydrocarbon, carbon monoxide, the particulate matters or the nitrogen oxides by combining the nitrogen oxide removal catalyst, the oxidation catalyst and the three-way catalyst.

The temperature Tin of the exhaust gas upstream of the DPF 3 varies greatly in accordance with the operating condition. Therefore, in the case where the upper limit value HCup of the quantity HCact of the hydrocarbon supplied to the DPF 3 is calculated from the temperature Tin of the exhaust gas upstream of the DPF 3, an averaged value of the plurality of sampled values of the temperature Tin may be employed for the sake of stable sensing. In the above embodiment, the hydrocarbon quantity sensing means calculates the quantity

HCact of the hydrocarbon actually supplied to the DPF 3 based on the operating conditions of the engine 1 and the like. Alternatively, the quantity HCact of the actually supplied hydrocarbon may be sensed with a hydrocarbon sensor disposed as hydrocarbon quantity sensing means. Alternatively, the hydrocarbon supply quantity controlling means may calculate the post injection quantity Qpost in advance so that the quantity HCact of the actually supplied hydrocarbon does not exceed the upper limit value HCup, considering the hydrocarbon poisoning.

The present invention should not be limited to the disclosed embodiment, but may be implemented in many other ways without departing from the spirit of the invention.